



## Kinder Morgan Liquids Tanks

Pasadena, Texas

**A Rammed Aggregate Pier® solution combining both Geopier GP3® and Impact® elements provided soil reinforcement to consistent depths of 30' in the variable fill to support tank pressures of 3,000 psf**

**Description:** Construction of two new above ground petroleum storage tanks, each measuring 150 feet in diameter and 52 feet in height. Tank bearing pressures are 3,000 psf.

**Subsurface Conditions:** The soil conditions consisted of variable cohesive fill extending to depths ranging from 20 feet to 28 feet overlying stiff cohesive soils. The cohesive fill exhibited shear strength values ranging from 160 psf to 3,000 psf. The very soft soils were typically found near the bottom of the fill. The fill also contained organic material, roots and rubble. Below the fill was predominately stiff to very stiff clay and sandy clay. Ground water was located in the fill at depths of 0 to 6 feet below grade.

**Geopier Solution:** Settlement of the tank placed on unreinforced soils would greatly exceed the design criteria of six inches in the center and three inches around the perimeter. In addition, edge instability factors of safety were less than 1.3. To reinforce the entire depth of fill, a Rammed Aggregate Pier® (RAP) solution combining both Geopier GP3® and Impact® systems was used to support the tanks. A total of 1,102 RAP elements were installed to a 30-foot depth. The upper 15 to 18 feet of each pier was then installed



using Geopier® elements measuring 30" in diameter. The combined solution provided a cost effective alternative to overexcavation and replacement to reinforce the soils throughout the complete fill depths.

### PROJECT TEAM

**Owner:**

Kinder Morgan Liquids Terminal

**Geotechnical Engineer:**

Fugro Consultants, Inc.

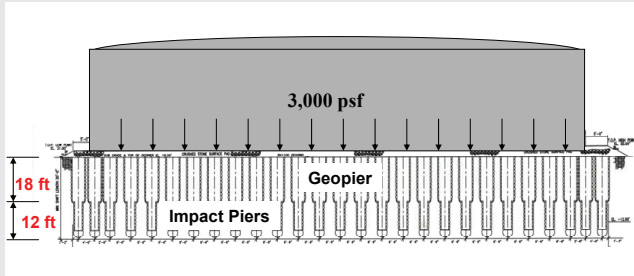
**Geopier Installer:**

Peterson Contractors, Inc.

**Geopier Designer:**

GFC-Houston

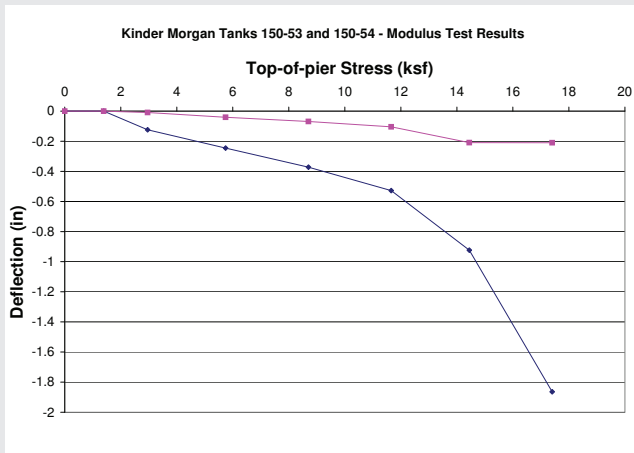
## MODULUS TEST PIER SETUP



The combined solution incorporated piers installed at 6.5 feet on-center. A 3-foot thick granular pad was constructed over the tops of the RAP elements to provide uniform support for the steel tank. The solution provides settlement control and increases in the edge stability factor of safety.

Results of the modulus test indicated a design stress of 15,000 psf would result in about one inch of settlement in the reinforced zone.

## MODULUS TEST RESULTS



The results of the modulus test indicate that a deflection of 0.9 inches was observed at a top-of-pier stress of 14,500 psf. At greater stress levels, the RAP exhibited a plastic bulging-type behavior with small increases in stress causing large increases in deflection. The tell tale installed at a depth of 15 feet indicated little stress reaching that depth. Based on the modulus test results, the design stress was limited to about 15,000 psf.